Java-Enabled E-Manufacturing Enterprise Design and Implementation

ABSTRACT

The paper reports efforts on constructing a J2EE-based e-manufacturing system where the front end ordering system, the middle layer distributed virtual enterprise, and the production control systems can be integrated using Java technologies. The plant-floor control is simulated in a virtual manufacturing cell and the verified operation plan can be transferred to a java-enabled real manufacturing cell.

INTRODUCTION

Broader product ranges, shorter model lifetimes, and the ability to process orders in arbitrary lot sizes are becoming the norm in today's manufacturing industry. The information processing capability to treat masses of customers as individuals is permitting more and more companies to offer individualized products while maintain high volumes of production (Goldman, 1995). The convergence of Intranet and Internet technologies is making it possible for groups of companies to coordinate geographically and institutionally distributed capabilities into a single "Virtual Enterprise", and in the process, achieve powerful competitive advantages. The key for ensuring the success of a "Virtual Enterprise" is to maintain agilities at all level in the organization and cross the whole spectrum of a complete product lifecycle (Iuliano, 1996). The main difficulty for achieving the promised agility lies on the effort to not just loosely bind all activities at the level of marking, design, organization, production, management, and human-resources together but to integrate them into a unified and efficient infrastructure where resource and information can flow freely and orderly to all sections in the virtual enterprise.

The Internet has been transforming the business world with the Web-based and customer-oriented technologies. It is anticipated the front-end ordering capability of e-commerce will one day be converged with the back-end execution processes of the production plants and hence ushering in a new era of collaboration between the factory floor and enterprise supply chain. So manufacturers will be able to handle business at the speed of the Internet (Slansky, 2002). Several capabilities are thought to be essential to transfer a traditional manufacturer to be a one equipped with the e-manufacturing power, namely a few, global accessibility, capacity and resource planning integration between the factory floor and supply chains, real-time factory operations and information visualisation across the Intranet and Internet, speed (time to market, service response, and product lifecycles) and production system flexibility.

PROMISES AND PROBLEMS OF E-MANUFACTURING

The potential of adopting global Internet as a common platform for exchanging information among companies and customers has been envisaged since the mid 1990s. Business-to-Customer (B2C), Business-to-Business (B2B) and other website operating modes have been hotly investigated. Along with the trend the e-manufacturing initiative has come on board (Xu, *et.al*, 2000). E-manufacturing involves a scope well beyond electronic data exchange, and execution of the production processes. It aims to transform traditional, proprietary control devices such as Programmable Logical Controls (PLCs) and Computer Numerical Controls (CNCs) to more open-structured virtual enterprise-enabled control and real-time information platforms. An industrial automation solution company – Emation – has been advertising a new Internet-based automation tool. It uses embedded Web servers to provide connectivity at the lowest level of plant floor control, and move real-time data from the device level to the controls level, and up to the enterprise tier. The essence of e-manufacturing is the ability to execute product design, production processes, collaborate with supplier, delivery, and customer cycles in real-time via the Internet. E-manufacturing extends beyond traditional factory floor operations in several areas critical to a company becoming Web-centric.

However, though promising and encouraged, the author believe before such a comprehensive and rational solution for transforming current aging global manufacturing industry can be realized, there are still fundamental questions to be answered, for example,

- how reliable is the information provided by a “virtual” customer through the hyper media of global Internet,
- does any manufacturer want to publish their highly sensitive business-interest related data on the largely unauthorized Internet, if not, how a credible “virtual enterprise” could be practically formed,
- is it viable to create an on-line supply chain controlled by software agents doing things no more than transmitting and receiving dates through email links.

If, arguably, the above questions are concerning only the domain of e-commerce but e-manufacturing, then,

- how would any plant managers like to have their manufacturing machineries being monitored and controlled by the faceless and performance-fluctuating Internet at real time.

To ask these questions does not mean the author is pessimistic or dismissing the possible advantages (or even revolutions) the Internet might brought to the global manufacturing industry, rather to encourage joint efforts from research institutions and manufacturing companies to solve those problems and lead to a successful e-manufacturing era together. In this paper, the author has focused on the technological side on the enterprise-level to test an Internet-based plant control system.

PROPOSED E-MANUFACTURING ENTERPRISE INFRASTRUCTURE

In this research, it is believed to allow practical implementation of some of the e-manufacturing functions promised in the above context, specifically manufacturing production functions, the enterprise information system (EIS)-tier needs to be clarified and it function modules populated.

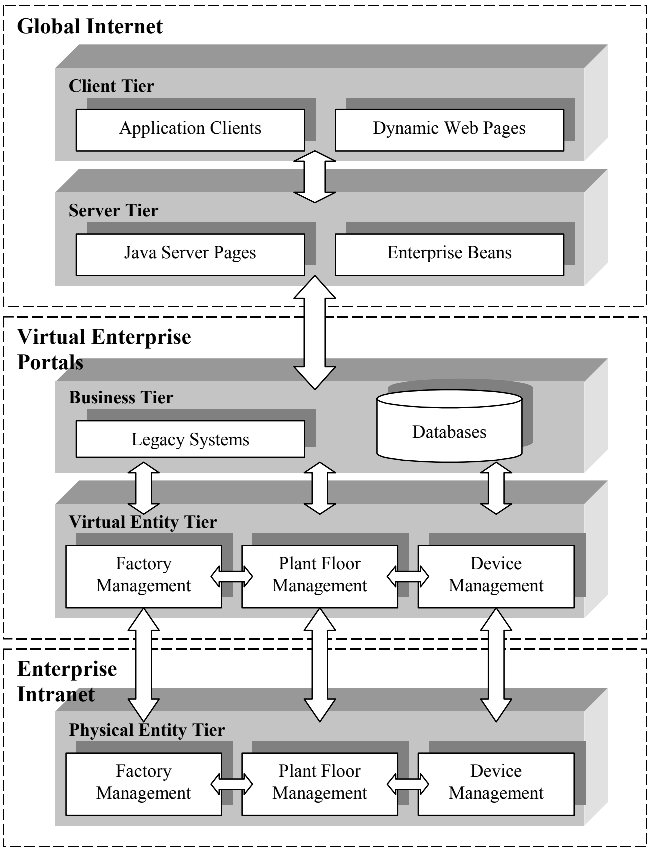

Figure 1. Virtual e-manufacturing enterprise structure.

Figure 1 shows the proposed J2EE-based e-manufacturing enterprise structure. At the top level, the Internet empowered client browsers, application programs, e-commerce websites with CGI, ASP, PHP, JSP, and Java bean-enabled functions provide company introduction, product inventory, contact details and on-line ordering services. This level of information exchange and data management forms the conventional concept of e-commerce where the business-to-customer (B2C) interface is constructed. The data collected from on-line customers and the data sent to update the websites are managed by enterprise database systems. This data service provider is different from ordinary Internet Service Provider (ISP) and relies on enterprise-level server machines to store and manage information. An enterprise bean living in the business tier receives data from client programs, processes it (if necessary), and sends it to the enterprise information system tier for storage. An enterprise bean also retrieves data from storage, processes it, and sends it back to the client program.

In the addressed structure the middle level of the e-manufacturing enterprise is what I call Virtual Enterprise Portals. Served by a common data back plane – the enterprise information system, this level of virtual e-manufacturing enterprise organises the enterprise supply chain, managing manufacturing resources, performing process planning and scheduling, managing plant information, and control the manufacturing processes. The enterprise information system handles enterprise information software and includes enterprise infrastructure systems such as enterprise resource planning (ERP), mainframe transaction processing, database systems, and other legacy information systems. Depending on the physical locations of production plants of a virtual enterprise, communications among various Intranets will also be established at this level. This is why this level has been named Virtual Enterprise Portals. The virtual entity layer is designed as a platform to model, simulate and probably visualize all the activities of a manufacturing enterprise, namely a few, factory production management and decision support, plant floor control, and factory devices and instrumentation control. It is designed in this structure for some of the simulation and control functions to be realized in virtual environments. Ideally, the environments should have logical and physical functionality of the simulated systems and be able to access all design and resource management data, and realizes behaviors of equipment or devices. Those VEs should be visualized across network and by various level of system users.

The bottom level of the proposed system structure is individual Intranets adopted by various manufacturing companies. It is consisted of factor management components, plant floor control components, and device control components. The simulation program designed and tested in a virtual environment should not only drive the virtual machines but transfers to the real entity tier and perform the real-life plant floor and device controls.

PROTOTYPE SYSTEM IMPLEMENTATION

A mock up e-manufacturing system has been developed based upon the proposed e-manufacturing infrastructure. The system is made up of components. Each component is a self-contained functional software unit that is assembled into a J2EE application with its related classes and files and that communicates with other components.

At the top of the prototype system is an enterprise level user interface (UI) installed on a client machine to collect ordering information. The interface program is designed and compiled using standard Java libraries (J2SE) downloaded from the website of the Sun Co. Ltd. A free downloaded Integrated Development Environment (IDE) – JCreator (Xinox Software) - was initially used to write the user-interface (UI) applet. The development platform was later changed to Java's SunOne platform for its powerful packing functionality to construct necessary web components to be put on the server machine. At the level of production, system architecture of self-describing objects with properties, methods, and interfaces, factory floor operations are defined using the Object-Oriented (OO) methodology. Factory automation objects are encapsulated with all of the functionality of the manufacturing process in self-contained Java classes. When a single object is instantiated it has a life of its own, complete with state, an ability to interface with other objects or components, and inherit the attributes and methods of other objects. Various Enterprise Java Beans (EJBs) at the portal level of the proposed system provide logical and efficient way to construct a set of manufacturing components that capture an entire plant floor operation.

The visualisation of the virtual plant floor was implemented through the Java3d style virtual environment authoriser. Each machines, devices, controllers and cells has a corresponding class defined (in Java and XML). A scene graph (the rendering structure) is formed by nodes that instantiated from classes. Started from a root node, the scene graph will determine "states" of each node, which can be treated as field (property) values of nodes. At run time, the activities of the virtual plant floor will rely on a so-called simulation manager to execute the task loop where objects in the environment could perform individual tasks while the VE is refreshed in real-time. A test virtual manufacturing cell was developed using Sense8 WorldToolkit (WTK) due to its simplicity to use and its similarity on the Scene Graph Structure to the Java3D.

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